SUNSHINE PERIOD FCC - 04-37

Attached is a PDF document containing a series of measurements from a BPL system in service near Cottonwood Arizona. The measurements were taken after "notching" was installed.

What is very noticeable is that even with efforts to minimize interference to the amateur radio bands, the signal levels from the BPL sites still impair HF operations.

In light of the numerous BPL sites that have shutdown operations due to interference, and countries that have rejected this technology, BPL is not a solution. At present this technology can not coexist with off air signals without conflict. Further research and development is needed if the BPL as it is today, should continue to operate.

Thru the Ethernet, past the Gateway, off the modem pool, nothing but NET . kit@ka0wuc.org

Cottonwood Arizona, and BPL

During the weekend of September 25th, 2004 a road trip was taken to Cottonwood, Arizona. The destination is nationally known for the BPL (Broadband over Power Lines) test site by APS (Arizona Public Service) using equipment manufactured by Mitsubishi. Data was collected at the three sites in the Cottonwood area; Sawmill Cove, American Heritage Academy, and Birch Street. The purpose of the trip was to measure, and gain a better understanding of BPL technology. To understand the effects of BPL, test equipment was verified for calibration, and a method of measurement was established.

The plots show that the broadband carriers are no longer within most of the amateur radio bands. In a conversation with Mike Kinney, KU7W, they were moved days prior to my arrival. Mike Kinney is a part of a team of members that is closely monitoring the progress of the BPL testing in his area, his team has been gathering data and furnishing it to the ARRL on a frequent basis. Plots show an elevated noise floor from a broadband carrier, which on average consumed 5MHz of spectrum. One of the sites still showed activity in the 15-meter, 17-meter, and 30-meter bands. Audio was collected using an Icom R10 tuned to anywhere in the carrier, and sampled to a laptop to create a ".wav" file. The Icom R10 produced a tone in CW-N, LSB, or USB modes, an audio tone was heard while the receiver was tuned anywhere within the BPL carrier.

The configuration used for measuring the BPL sources closely emulated an HF mobile operation commonly used in the amateur radio bands. The data collected employed a 7-foot whip antenna on the rear lift gate of a Jeep Cherokee. The antenna is part of the SGC (http://www.sgcworld.com) QMS-7 package. The package includes; a mounting kit, an externally mounted auto-tuner, and a 7-foot whip antenna. Functionality of the system was verified prior to testing the BPL sources within the amateur radio HF bands. To insure that the tuner wasn't altering the measurements, it was put into the "reset" condition. The "reset" condition removes all inductors and capacitors from the RF path, leaving the 7-foot whip antenna connected directly to the coax. This configuration allowed for a worse case tune of the antenna, which offered the most attenuation of the signal. A resonant antenna would present less loss of the frequency of interest. The noise floor was measured a quarter mile from the closest BPL test sites. The power source to run all the test equipment was a Hewlett Packard HP-85901A DC to AC voltage inverter. The HF whip antenna was connected to a Hewlett Packard HP-8951A RF spectrum analyzer with 6 feet of RG-213. Each BPL test site was sampled, looking closely at the HF portion of the spectrum. Data plots were then downloaded into a laptop with "Print Capture," software that communicates with the spectrum analyzer. The HF whip with tuner represented a system commonly used, but with degraded performance, as the tuner was not optimized for the frequencies under investigation. It was not practical to emulate a traditional HF base station, as the installation of a tower and beam antenna are difficult to setup for a temporary measurement. An HF mobile installation performs with less gain than a base station due to the size limitations of antennas used on a vehicle, versus those used on a tower.

Testing

Locations near the utility poles outfitted with BPL equipment were selected to take measurements. The three sites were visited and measured in a random order. No site had a priority or preference to another.

While at each location, the vehicle was parked within 10 meters slant distance of the utility pole's coupling point between the BPL equipment and the medium voltage lines. These are seen in the photographs as large red insulators. Distance was measured using a Bushnell Range Finder that was configured to display distance measurements in meters.

The engine was turned off; the spectrum analyzer and power source were turned on. The power on self-test was allowed to complete on the spectrum analyzer prior to attaching it to the antenna. The spectrum analyzer had been running on a separate AC inverter while the vehicle was in transit, allowing the instrument to stay operational and stabilize. The spectrum analyzer was attached to the QMS-7 in lieu of the HF transceiver. The reset button on the tuner was pressed and held until the "tune" LED was extinguished.

Brief scanning of the HF spectrum was performed using the spectrum analyzer. Once a broadband carrier was found that was not readily identifiable, it was monitored with the Icom R-10 handheld receiver. If the distinctive tone and clicking pattern was heard, further analysis was performed with the spectrum analyzer. If a broadband carrier was found and did not have the characteristics of BPL, it was ignored.

Plots were taken with the antenna not tuned to any specific frequency; therefore the gain of the antenna is less than a resonant antenna. Plots of the various carriers were stored into the laptop via the HPIB (Hewlett Packard Instrument Bus, also known as GPIB or IEEE-488) interface from the spectrum analyzer to the laptop. Captured plots were tagged with a name and date/time stamp of creation.

Photographs were taken of the sites with an Olympus C-3040ZOOM digital camera. The photos were also date/time stamped when created, and later transferred to the laptop for inclusion of this report.

Conclusion

The distances on average from each BPL test site were within 10 meters for the measurements. Signals were observed, and very noticeable within a city block, approximately 200 meters, of any of the test sites. With the sensitivity of a typical HF receiver used in amateur radio communications (-121dBm), a BPL site could be heard as far away as a mile. The plots taken from this specific test are considerably lower readings due to the type of antenna used for the sampling of data.

BPL is not shielded or containing the RF generated by the electronics used to transfer the broadband data on power lines. When comparing BPL to CATV (cable TV) one must remember that CATV is shielded which offers containment of the RF. The shielding of CATV is the fundamental reason why it can coexist with off-air services. BPL on the other hand is not shielded and not contained. It is this lack of containment with BPL RF that prevents it from coexisting with off-air services.

BPL, if allowed to continue operation in the United States would seriously hamper HF communications, if not disable it completely. HF is used not only by amateur radio operators for pleasure, but also in times of emergencies or natural disasters when other methods of communications fail. HF spectrum is an asset to the nation when used by amateur radio operators without the impairment of BPL.

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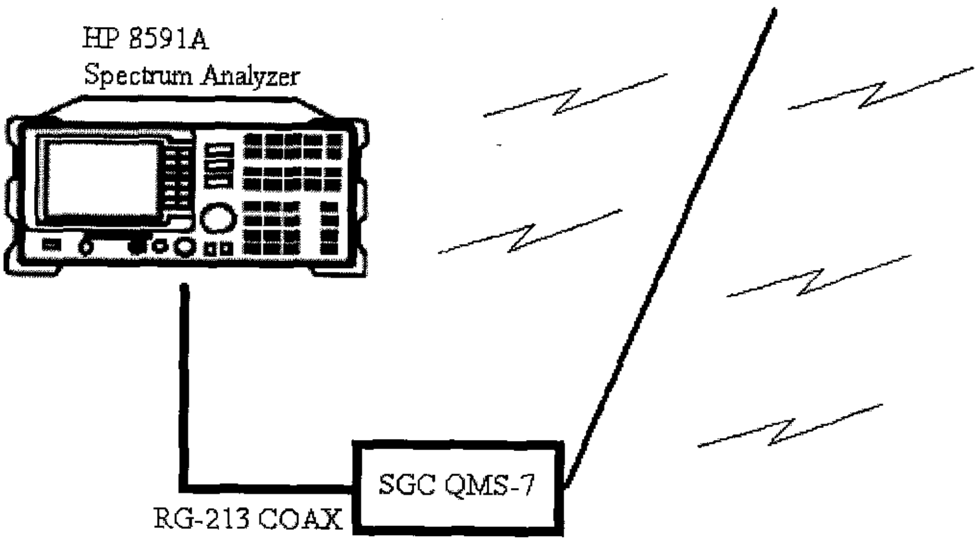
PG-GB-013355

Testing configuration and inventory

The scale on the spectrum analyzer is logarithmic; each division is ten fold greater than the one below. The scale is referenced to 1mW ($1*10^{-3}$ watts into a 50Ω load) where 1mW is 0dBm.



(Figure 1. Test setup)

Above is a block diagram showing the test configuration used for measuring the BPL signals. The QMS-7 with the 7-foot whip antenna was mounted on the lift gate of a 1996 Jeep Cherokee. The RG-213 was attached to the spectrum analyzer with a SO-239 to N male adaptor, as the instrument has an N female jack on the front.

Manufacture	Model	Description	Calibration Date
Hewlett Packard	HP 8591A	RF Spectrum Analyzer 9 kHz to 1.8 GHz	Jun-05
Hewlett Packard	HP 85901A	DC to AC power source Portable ac power source	N/A
Icom	ICR-10	General Coverage Handheld Receiver 500 kHz to 1.3 GHz (cell blocked)	Self Cal
SGC	QMS-7	Mobile HF whip antenna	N/A
Bushnell	Yardage Pro 1000	Laser range finder	New Jan-04
Dell	Latitude XPi	Laptop with software to record audio and spectrum analyzer traces	N/A
Olympus	C-3040ZOOM	Digital camera	N/A
Jeep	Cherokee	1996 Jeep Cherokee	N/A

(Table 2. Equipment Used)

Data conversion

A typical receiver used in amateur radio has a loosely calibrated "S-Meter" used to indicate the signal strength of the incoming signal. The meter is simply a voltmeter also in a logarithmic scale. Each division on an "S-Meter" indicates an increase of 6dB of voltage on the receiver. The ARRL handbook refers to an old standard of S9 calibrated at 50 microvolts RF input and 6 dB per S unit down from that reference point. The S unit is what most amateur radio operators are familiar with when evaluating the received signal. The dBm scale is familiar to those in engineering practices.

Using the dB scale to measure gain or loss: $dB = 10 * \log\left({out}/{in}\right)$ some substitutions are used to reference this towards the 1mW level:

in = 1mW out = $\left({V^2}/{R}\right)$

V = volts (1μV would be 0.000001V)

R = impedance (usually 50Ω)

With the elements substituted the whole equation from microvolts to dBm is derived:

$$dBm = 10 * \log\left(\frac{V^2}{50\Omega} \bigg/ 1mW\right)$$

(Equation 1. dBm from Volts)

Rearranging the formula to solve for the microvolts from dBm. Converting from dBm to microvolts will ultimately get the S units from the plots of the spectrum analyzer:

$$V \approx \sqrt{R * 1mW * 10^{\left({dBm}/{10}\right)}}$$

(Equation 2. Volts from dBm)

Converting from dBm to dBμV simply take the dBm value and add 107:

0dBm = 107 dBμV

(Equation 3. dBm to dBμV)

S-9 is 50μV into a 50Ω load; using equation 1, S-9 would correlate to –73dBm.

S Unit	dBm	dBW	dBμV (50Ω)	Microvolts (50Ω)
S1	-121	-151	-14	0.2
S2	-115	-145	-8	0.39
S3	-109	-139	-2	0.78
S4	-103	-133	4	1.56
S5	-97	-127	10	3.13
S6	-91	-121	16	6.25
S7	-85	-115	22	12.5
S8	-79	-109	28	25
S9	-73	-103	34	50
S9 + 10dB	-63	-93	44	158.3
S9 + 20dB	-53	-83	54	500.5
S9 + 30dB	-43	-73	64	1583

(Table 2. S Units)

Field Strength:

$$dB\mu V\Big/_{m} \approx dBm + 107 + AntennaFactor(@\,frequency)$$

(Equation 4. dBμV/m from frequency of operation and spectrum analyzer reading)

Bandwidth Conversion:

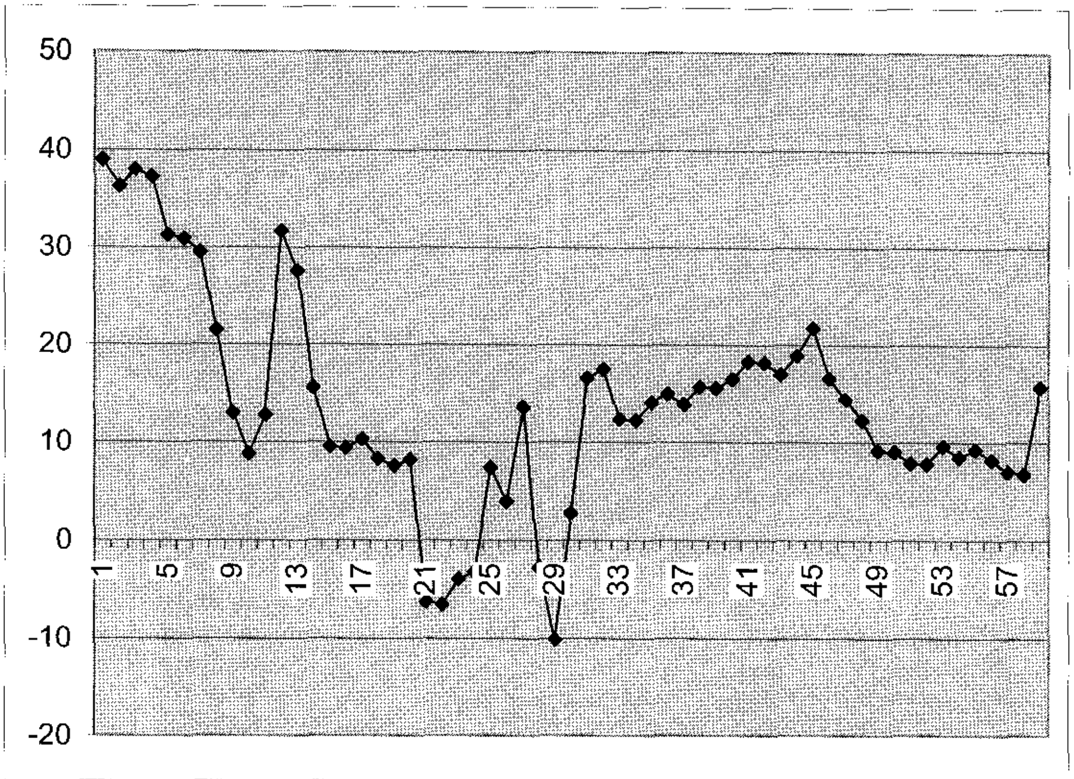
$$Bandwidth\_Correction \approx 10 * \log\left({new}\Big/_{old}\right)$$

(Equation 5. Converting bandwidth)

Example: $-5.22879 \approx 10 * \log\left({9KHz}\Big/_{30KHz}\right)$

When inspecting the plots, any point on the graph above –73dBm is a signal that is equal to or greater than S9 on a typical amateur radio HF receiver. The same point is at 34dBμV or greater.

Antenna Factor of QMS-7



(Chart 1. QMS-7 Antenna Factor from 2MHz to 60MHz)

The chart above is a derivation of the QMS-7's performance when performing a relative measurement against the ETS-Lingren passive loop and biconical EMC antennas. The chart shows the Antenna Factor from a range of 2MHz to 60Mhz.

To determine the field strength of the measured signals on the spectrum analyzer, the frequency and amplitude must both be known. Looking on plot #3 from American Heritage Academy, it shows a point around 35MHz that is approximately –65dBm.

The field strength from that plot is determined to be:

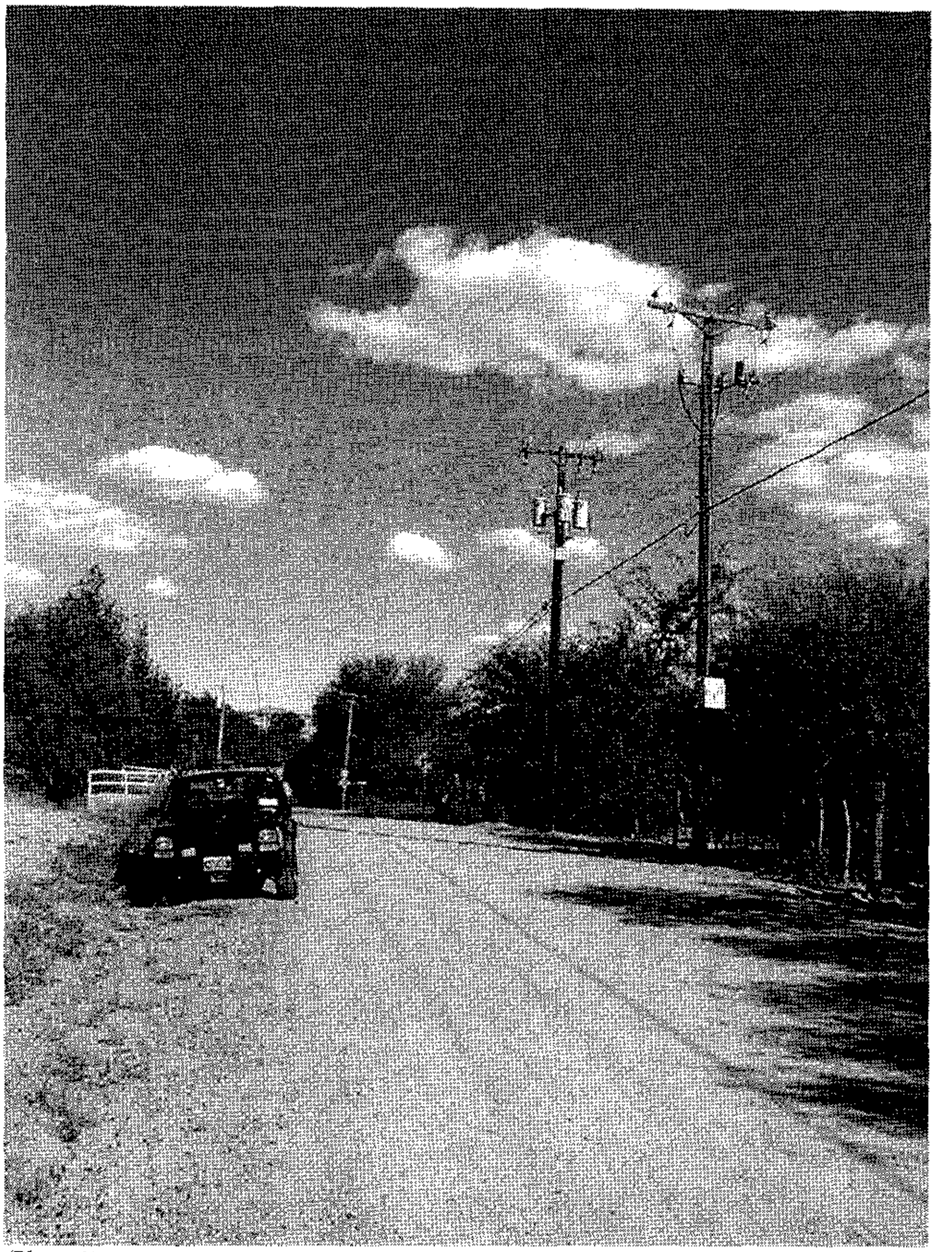
52.3dBμV/m

-65dBm + 107dB + 12.3dB (Antenna Factor at 35MHz) = 54. 3dBμV/m

Freq (MHZ)	Antenna Factor (dB)	31	2.8
2	39	32	16.6
3	36.3	33	17.5
4	38	34	12.4
5	37.3	35	12.3
6	31.3	36	14.1
7	30.9	37	15
8	29.5	38	13.9
9	21.5	39	15.7
10	13	40	15.6
11	8.8	41	16.5
12	12.8	42	18.3
13	31.7	43	18.2
14	27.6	44	17
15	15.6	45	18.9
16	9.5	46	21.8
17	9.4	47	16.6
18	10.3	48	14.5
19	8.3	49	12.3
20	7.6	50	9.2
21	8.2	51	9
22	-6.2	52	7.9
23	-6.5	53	7.8
24	-3.9	54	9.6
25	-3.2	55	8.5
26	7.4	56	9.3
27	4	57	8.2
28	13.6	58	7
29	-2.7	59	6.8
30	-10.1	60	15.7

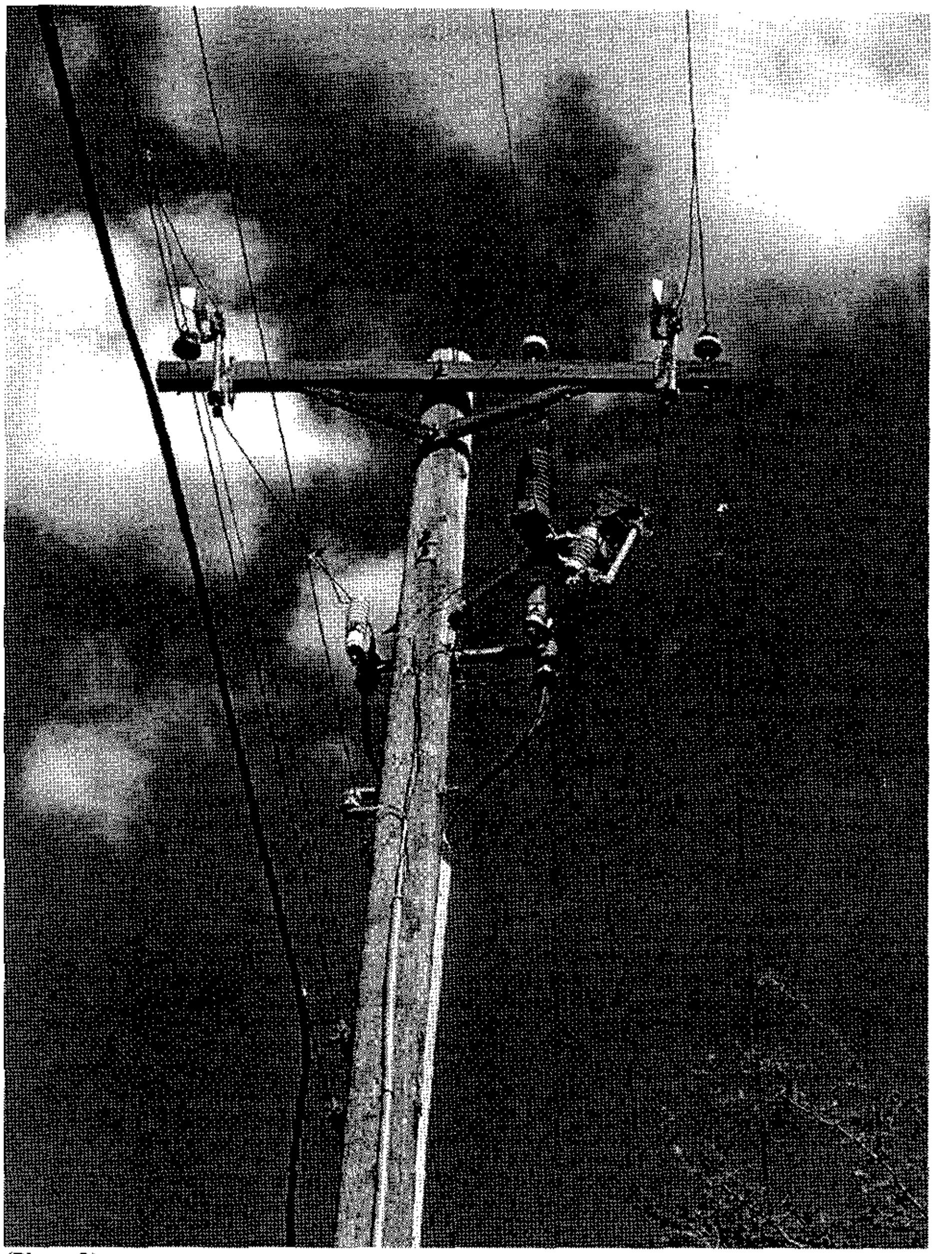
(Table 3. Antenna Factor of QMS-7 by frequency)

Sawmill Cove



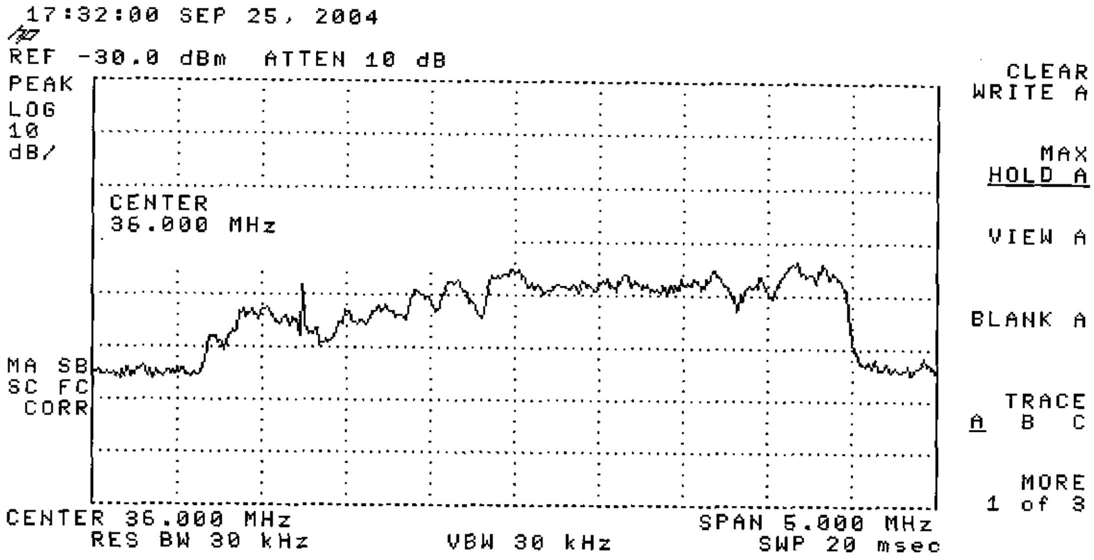
(Photo 1)

The utility pole on the near right shows a red insulator that couples a wire to the box further down at the 8-foot level. Measurements where taken along the side of the road, as shown in the photo. Signals were still present at or near the same amplitude along the span to the next utility pole. The medium voltage line appears to radiate the signal like a horizontal antenna. Horizontal polarity is the dominant polarity used in HF base station communications.

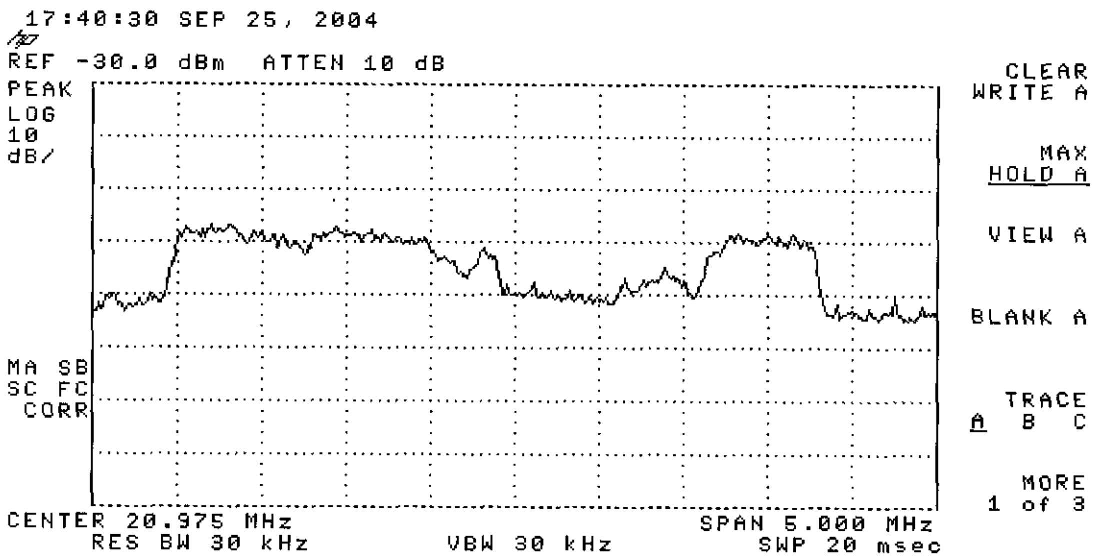


(Photo 2)

Closer photo of the BPL equipment mounted on the utility pole. The red insulator is a hint that BPL is present on this utility pole. A medium voltage line is run down the center of the pole, protected with PVC or other plastic material to the box which houses the electronics further down the pole. The BPL signal is not shielded with the PVC or plastic material, allowing it to radiate with vertical polarity. Vertical polarity is the dominant polarity used in mobile HF communications.

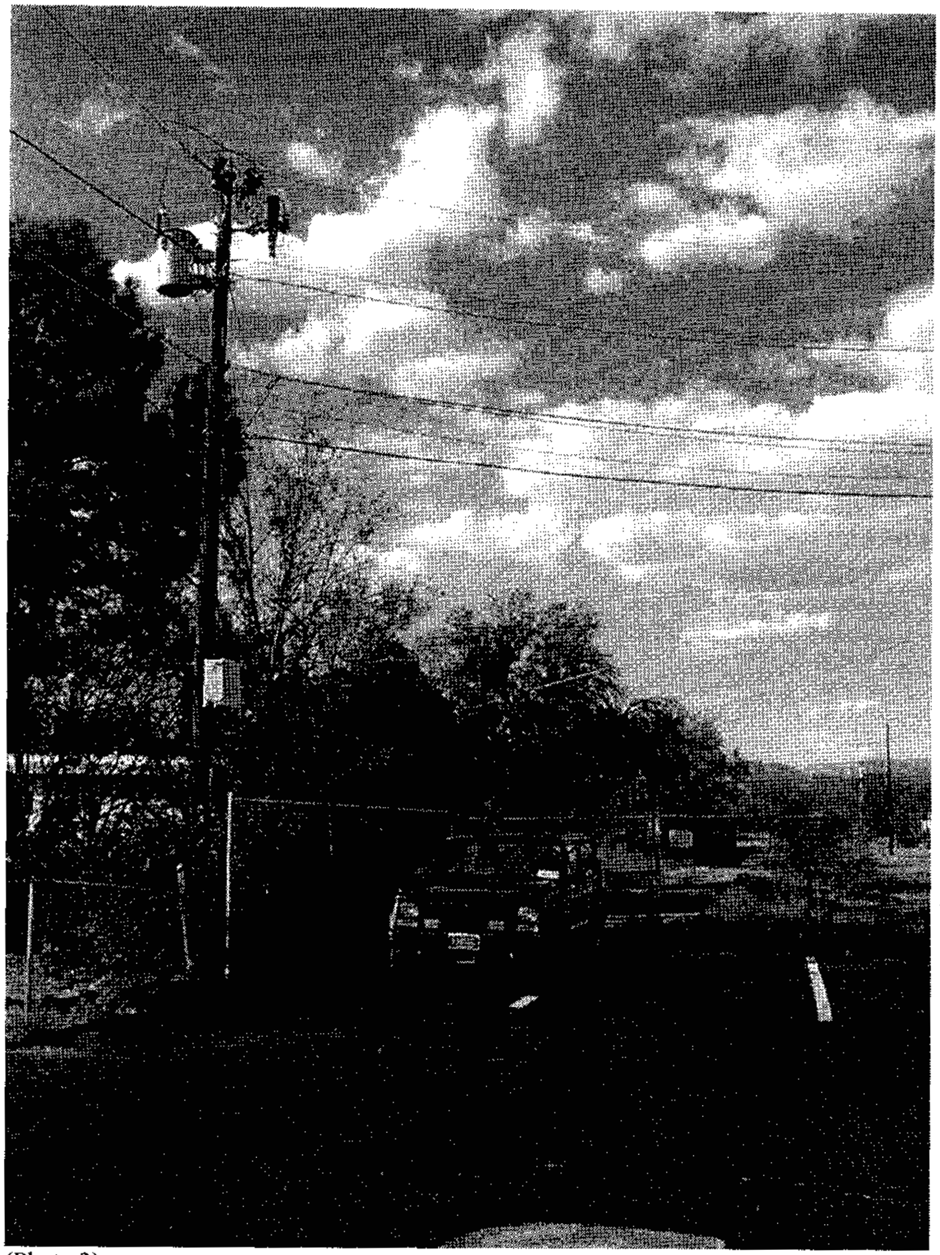


(Plot 1)
A sample of HF spectrum around 36Mhz, the width of the span is 5Mhz; each division is 0.5MHz. The range of the plot is from 33.5Mhz to 38.5Mhz, there are no HF amateur bands in this portion of the spectrum. The signal is on average S9+ on an HF receiver.



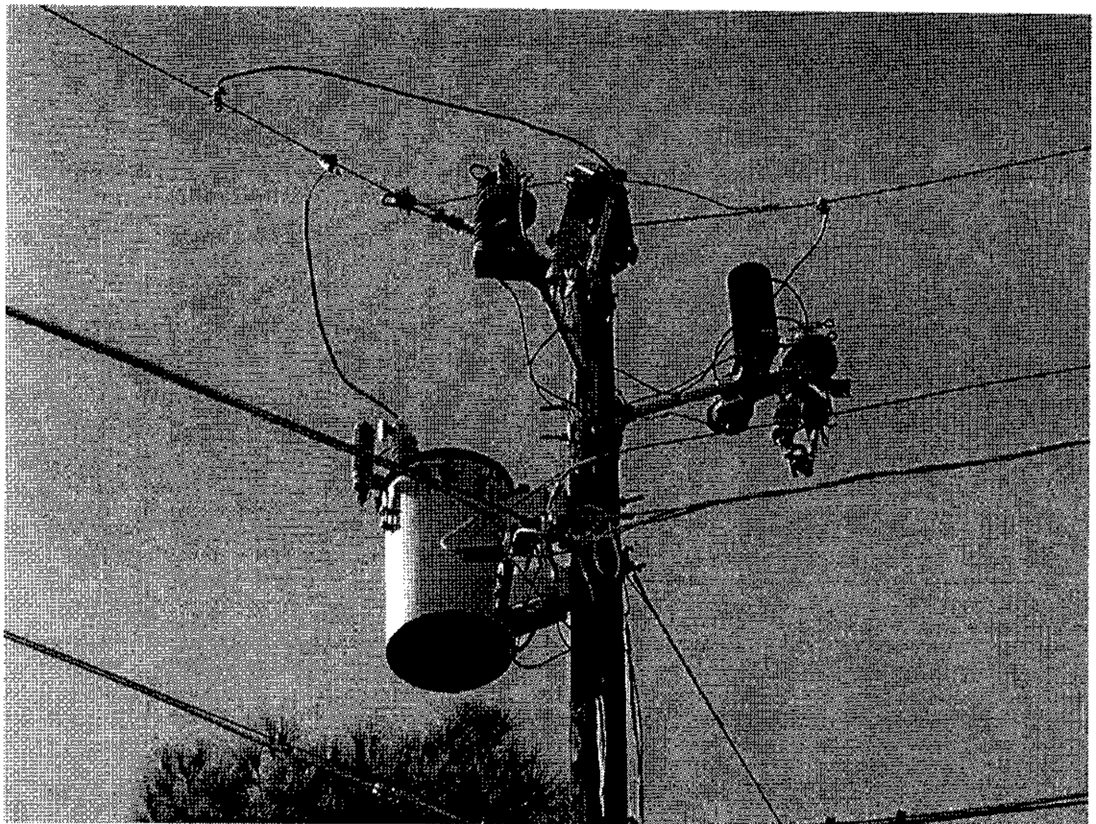
(Plot 2)
This plot shows a second set of carriers, 18Mhz and 22Mhz at –60dBm. The 4th vertical column from the far right is the amateur 15-meter band (21.100MHz to 21.450MHz). The signals represent S9+10dB on an HF receiver.

American Heritage Academy



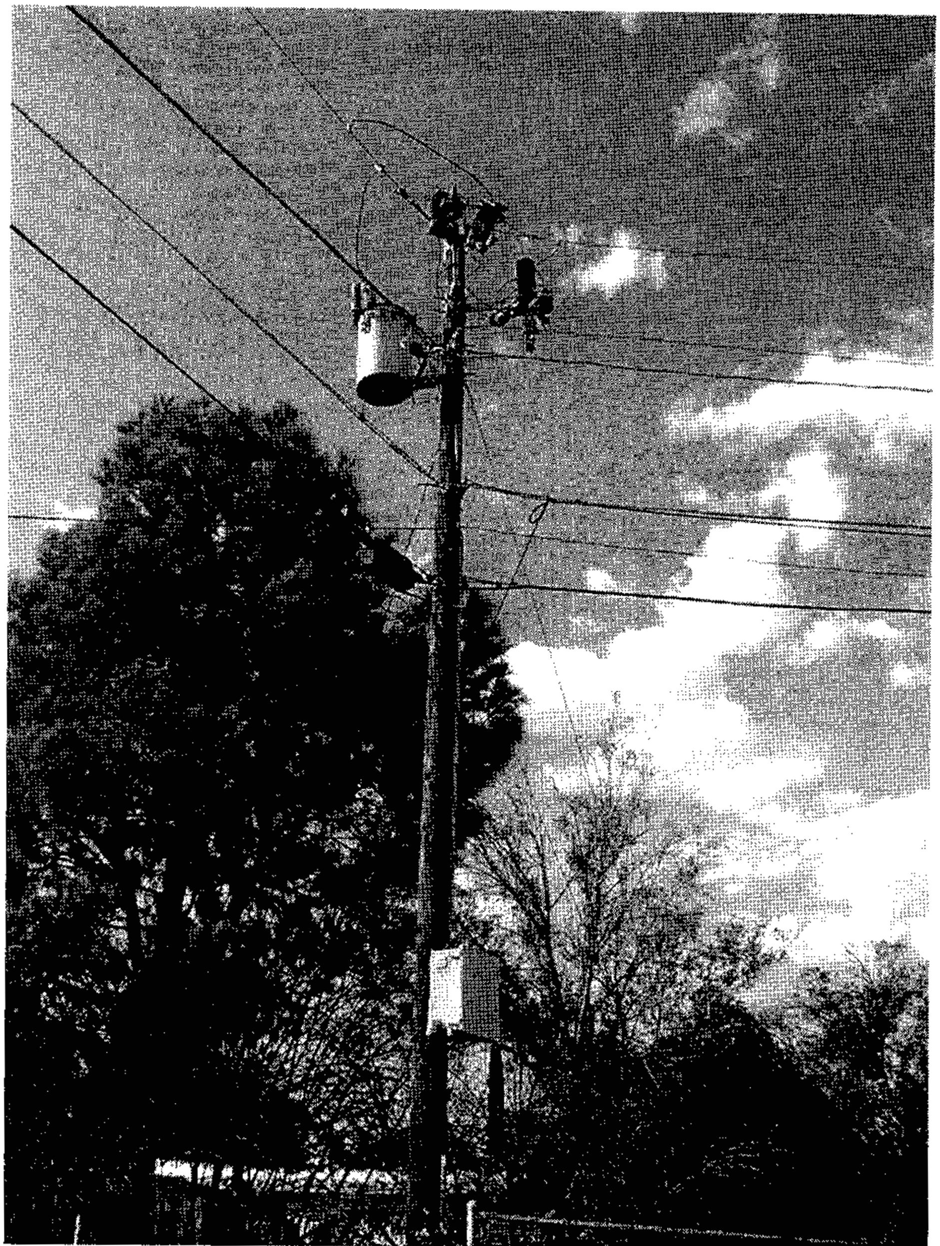
(Photo 3)

Notice the red insulator on the utility pole at the second test site. The box mounted at about 8-feet is the housing for the electronics of BPL. The vehicle was moved after the photo was taken, positioned here for a reference.



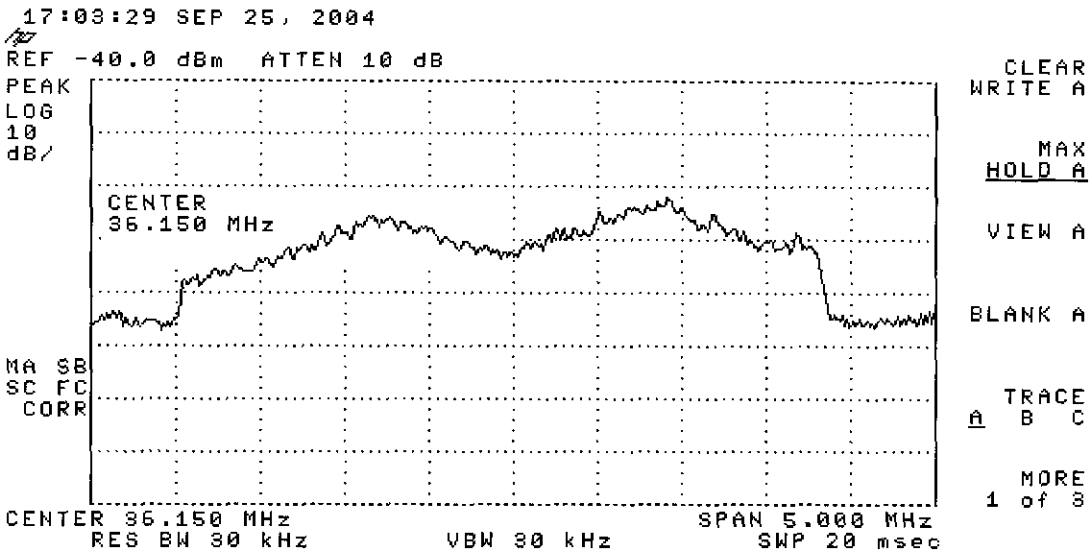
(Photo 4)

Close up detail of the BPL wiring that was added to the utility pole. The red insulator is attached to a wire that is run down to the electronics box at a lower level. The BPL signal is capable of radiating on the vertical and horizontal runs of wire.



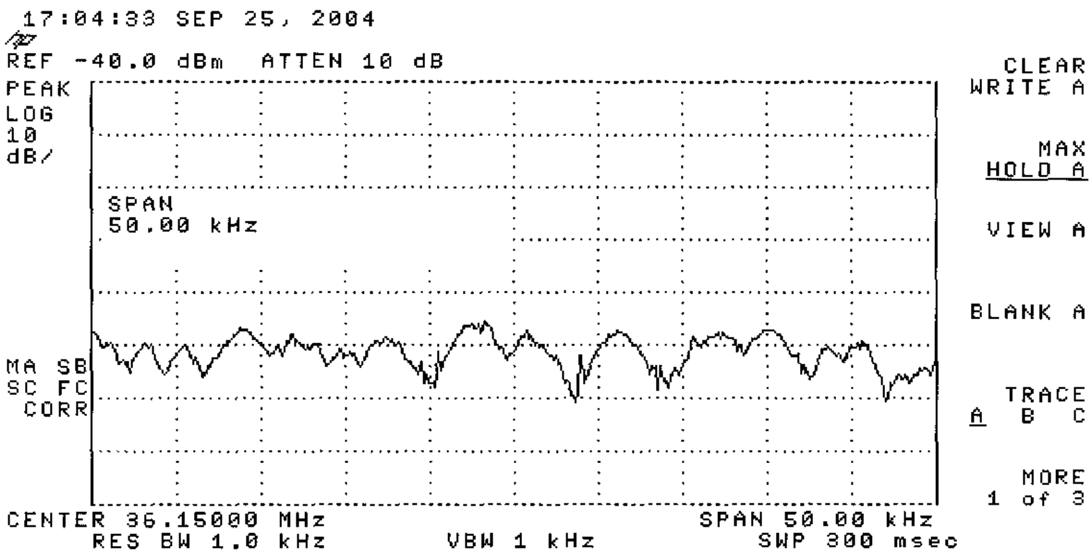
(Photo 5)

Shown is the box that houses the equipment, which is attached to the medium voltage lines further up on the utility pole. Note the PVC or other plastic material used to protect the medium voltage line that is run down the pole to the box with the electronics equipment.



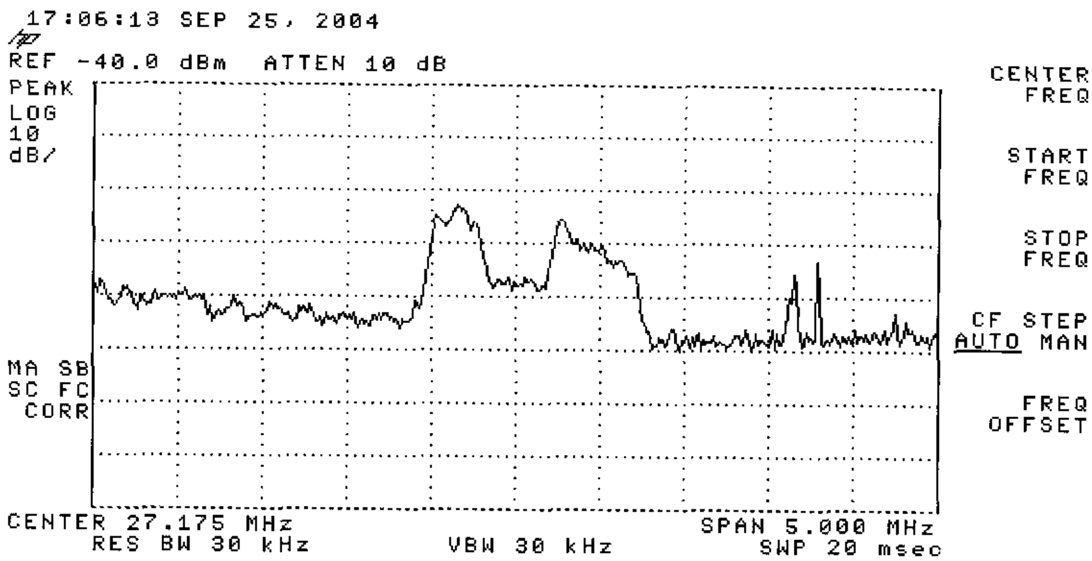
(Plot 3)

The signal looks like two broadband carriers positioned side-by-side in the spectrum. These carriers are not within amateur radio allocation, but again sampled to learn the effects of BPL. When monitored with a HF receiver the signal strength would exceed S9+10dB.



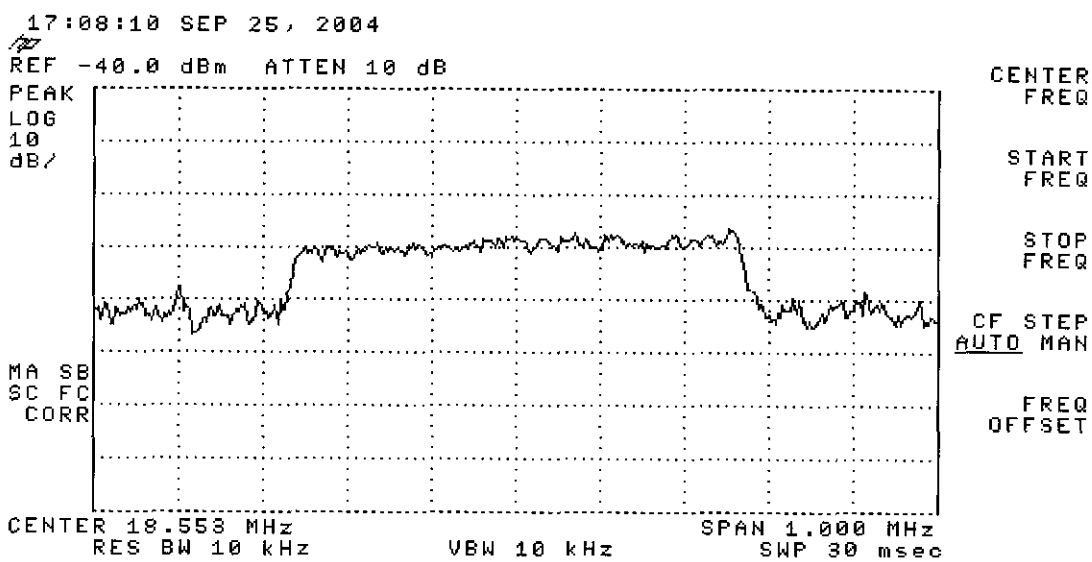
(Plot 4)

Span zoomed to show individual carriers randomly spaced near 5KHz from each other. As the ICOM R-10 receiver was tuned anywhere between 34.150MHz and 37.900MHz a tone with a cyclic clicking was heard on the receiver in the following modes: CW-N, USB, and LSB.



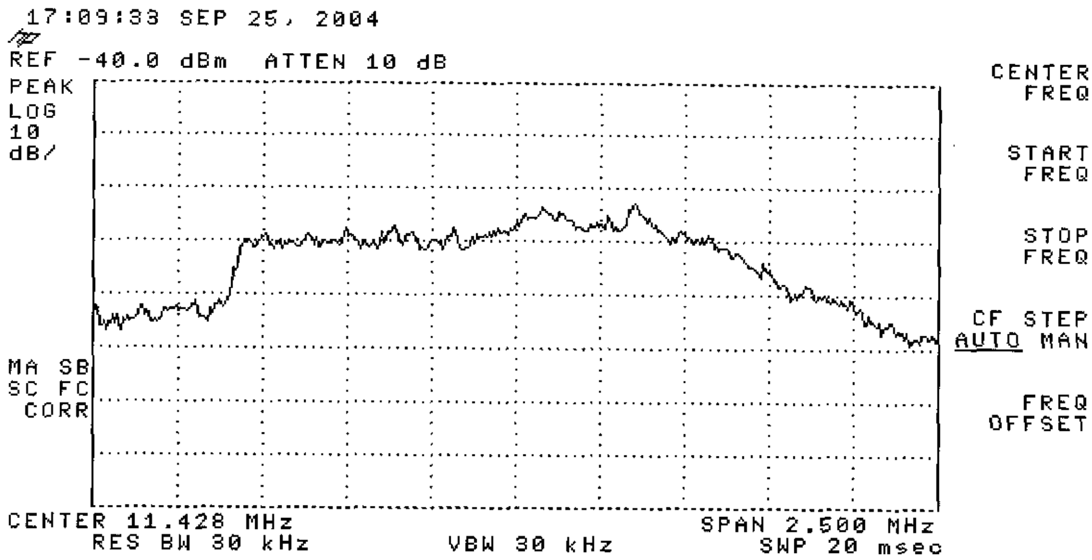
(Plot 5)

These carriers were also noticed, and are in the Citizens Band portion of the HF spectrum. While watching the site in a broader span, these carriers along with the carriers present at 36MHz came up and down together.



(Plot 6)

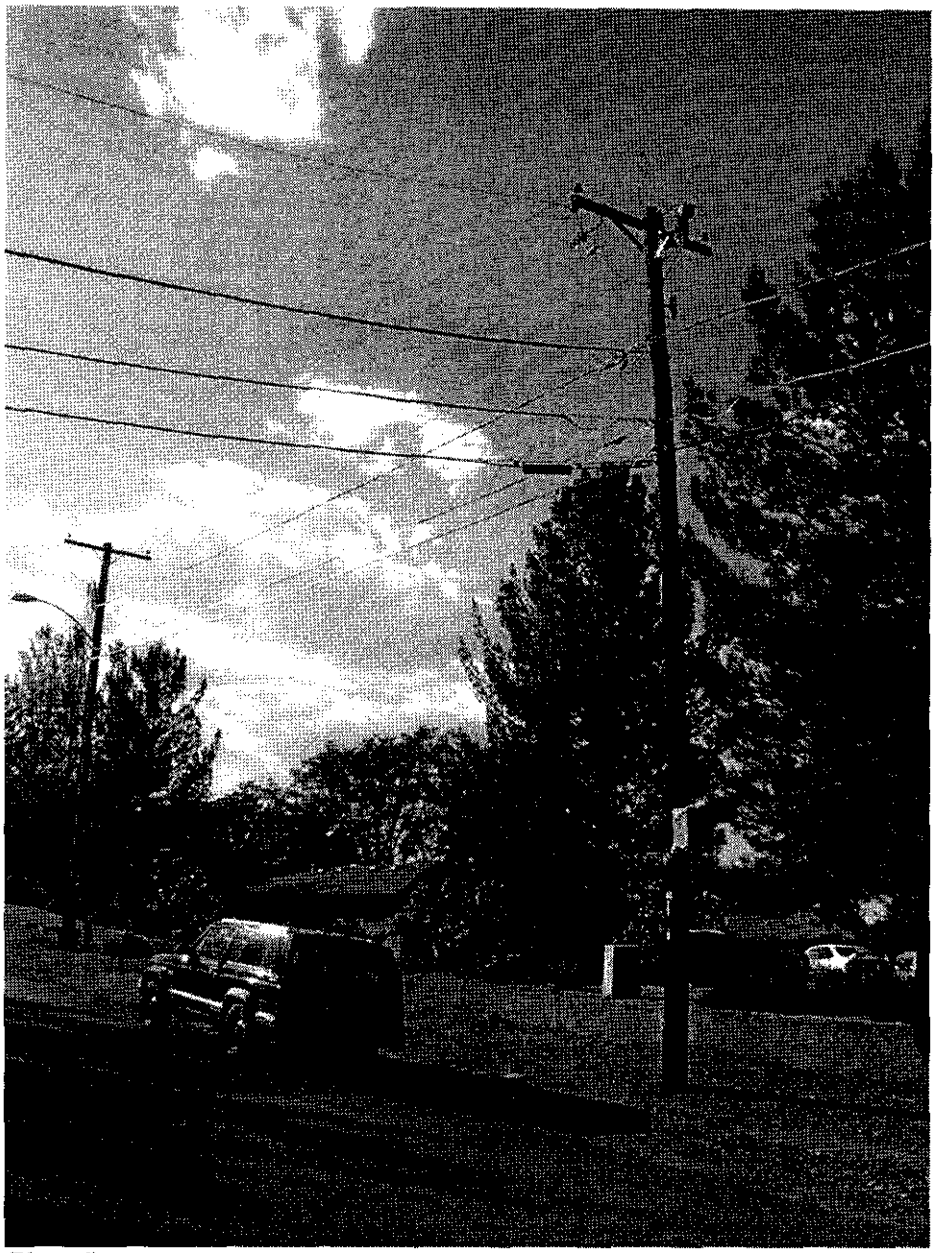
This carrier is centered on 18.55MHz, but with a bandwidth of 600KHz, it does approach the 17-meter band (18.068MHz to 18.168MHz) at a level equal to S9+ on an HF receiver.



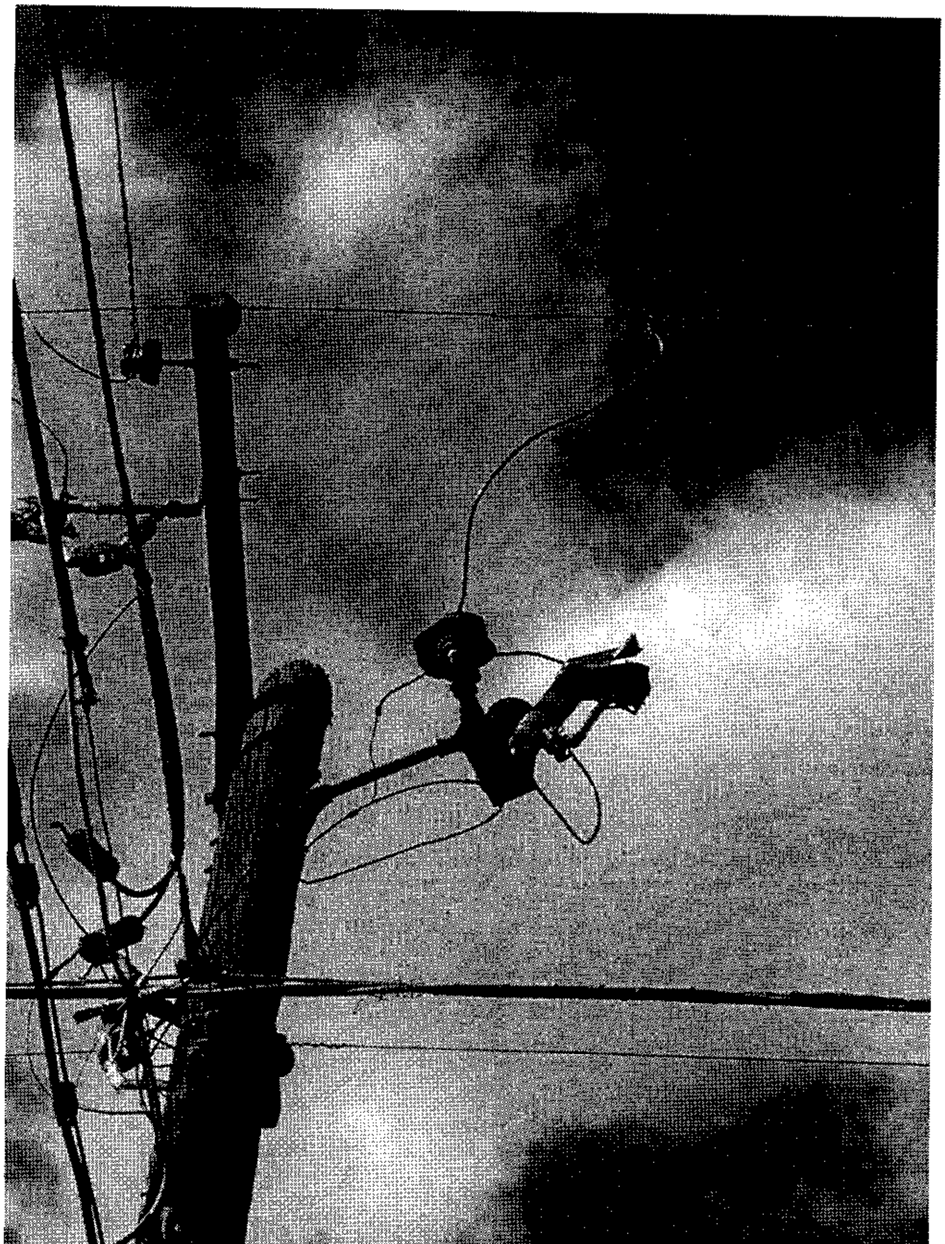
(Plot 7)

This carrier is also out of the amateur radio bands, but is close enough to interfere with 10MHz WWV reception. I was able to receive 10MHz WWV when this site was atleast ¼ mile away. As I approached this BPL test site, the noise floor captured the receiver. This carrier also hampers the ability for amateur radio operators to use the 30-meter band (10.100MHz to 10.150MHz) with a reading approaching S9+ on an HF receiver.

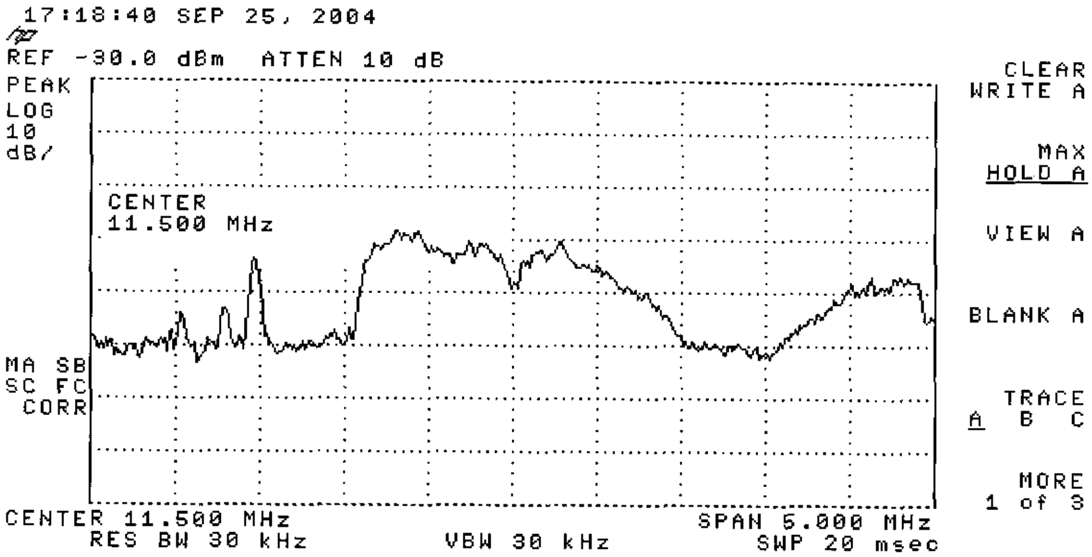
Birch Street



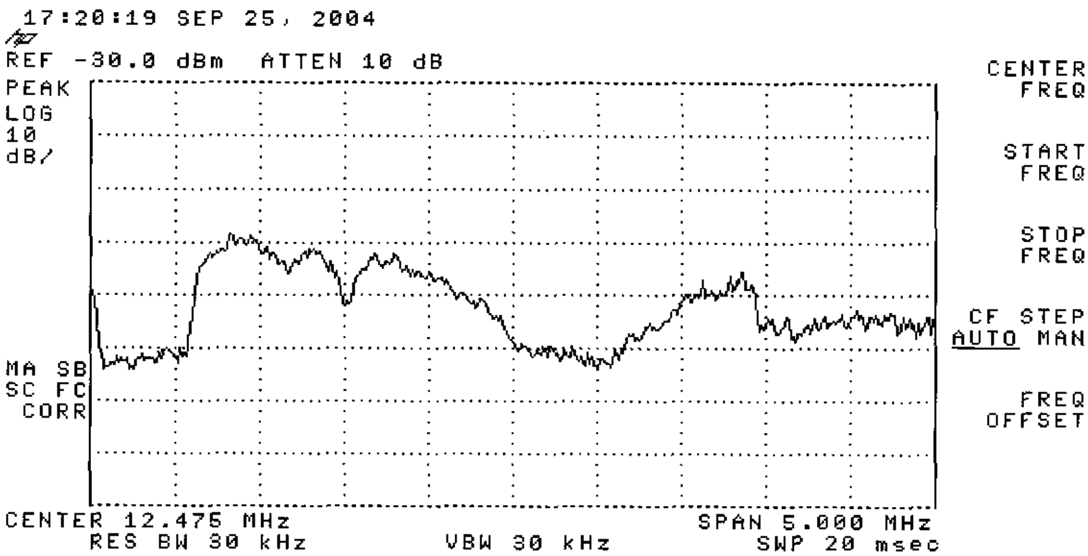
(Photo 6)
Birch Street shown with the equipment mounted on the pole on the right side of the photo. The Jeep was moved around this block and found uniform signal strength from the BPL equipment. The vehicle was positioned 10meters from the coupling point of the BPL equipment when the measurements were taken.



(Photo 7)
Birch Street BPL test site showing the red insulator and wire that is run from the medium voltage, down the pole, to a box that houses the electronics equipment used for BPL transmission.



(Plot 8)
The carriers centered around 11.5MHz are strong enough to interfere with 30-meter (10.100MHz to 10.150MHz) operations. WWV on 10MHz was difficult to receive.



(Plot 9)
Additional carriers from the same BPL test site are present around 12.5MHz. This is strong enough to eliminate any ability to receive short wave broadcast services.